PATENT SPECIFICATION 954,593

DRAWINGS ATTACHED.

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954,593

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International Classification:—**H 05** g (C 23 c, G 21).

COMPLETE SPECIFICATION.

Shield for Ionizing Radiations.

We, GENTEX CORPORATION, a Corporation duly organized and existing under the laws of the State of Delaware, United States of America, of 450 Seventh Avenue, New York, New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a shield for ionizing radiations and more particularly to a protective shield having improved properties over radiation shields known in the prior art.

It is known in the prior art that lead resists penetration by ionizing radiation at the lower energy level. Lead in the form of thick shields or sheets is use to afford protection against harmful effects of such radiation. While this form of shield is satisfactory in many instances, in other cases the shields such as are known in the prior art are not satisfactory. For example, where the shield has a relatively simple form, a sheet may readily be shaped to this form. Where, however, the shield is to have a relatively complex contour, such as where it is to be used to protect parts of a patient's body internally or externally other than those being subjected to medical treatment from the effect of radiation, formation of a sheet to the required shape is difficult. Similar conditions apply to the shielding of the bodies of persons who are occupationally exposed to radiation, like maintenance crews of reactors and persons similarly employed. Sheets or plates of lead also are useful where the shield is permanently formed to the shape in which it is used and where it is not required to flex or bend in use. It will be appreciated that sheet or plate lead is not as satisfactory as is desired where a protective garment is to be formed. In such a case the protective sheet or plate is diposed in pockets in a garment, thus leaving many parts of the body exposed to the harmful effect of radiation. Not only is sheet lead difficult to shape into many desirable forms but also it is extremely heavy for the amount of protection afforded.

The present invention is concerned with a shield for ionizing radiations which at once protects against the harmful effect of ionizing radiation and at the same time is pliable to permit it to flex in use. The radiation resistant shield is readily formed to any desired shape such, for example, as the shape of a garment, has sufficient structural strength to support its own weight in use without damage, has good structural stability, and pound for pond, affords greater protection against ionizing radiation than does a lead sheet. In addition, the shield resists heat for a long period of time.

The invention is also concerned with a method of making a shield for ionizing radiation and having the desirable characteristics outlined above.

Accordingly the invention provides a shield against ionizing radiation comprising a base layer and a layer including lead amalgam secured to the base layer.

The invention further provides a shield against ionizing radiation comprising a plurality of lengths of material each including a base layer and layer including lead amalgam and a carrier formed with pockets for receiving the lengths, the side walls of the packets extending diagonally such that the edges of said lengths overlap.

In another aspect the invention provides a method of making a shield resistant to

ionizing radiations comprising the steps of brushing the opposite faces of a bass layer of thermal cloth to raise piles on the faces, applying lead amalgam layers to said faces and retainling the lead amalgam layers on the base layer.

In still another aspect the invention provides a method of making a shield resistant to ionizing radiation comprising the steps of brushing the opposite faces of a base layer of thermal cloth to raise piles on the faces, applying layers of lead to the faces, treating the coated base layer with mercury to form lead amalgam, removing the excess mercury from the amalgam and retaining the amalgam layers on the base layer.

In the accompanying drawings which form part of the instant Specification and which are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:—

Figure 1 is a sectional view of one form of shield for ionizing radiation.

Figure 2 is a weaving diagram illustrating the manner in the central heat resistant layer of the shield shown in Figure 1 is formed.

Figure 3 is a sectional view of the central heat resistant layer of the shield shown in Figure 1 after its surfaces have been brushed.

Figure 4 is a fragmentary view of the shield showing one means for holding the shield layers in assembled relationship.

Figure 5 is a fragmentary view of the shield showing an alternative means for holding the shield layers in assembled relationship.

Figure 6 is a graph demonstrating the effectiveness of the shield in resisting penetration by radiation in terms of an equal weight of lead.

Figure 7 is a fragmentary sectional view of another form of shield for ionizing radiation.

Figure 8 is a fragmentary sectional view showing one manner in which a shield for ionizing radiation may be incorporated in a supporting structure.

Figure 9 is a fragmentary sectional view showing a manner of forming pockets for the reception of lengths of a shield for ionizing radiation.

Referring now more particularly to Figures 1 to 5 of the drawings, one form of shield for ionizing radiation, indicated generally by the reference character 10, includes a central layer 12 of a heat resistant fabric.

As is shown in detail in Figure 3, the fabric layer 12 comprises a plurality of large gauge wefts 14 bound together by intersecting woven binding fabrics 16, 18, and 20. The large gauge wefts 14 are formed for the most part from a material which passes directly from the solid to the gaseous state upon the application of heat. Materials which are suitable for this purpose are acrylic fibres such, for example, as Dynel and the material sold under the Registered Trade Mark "Orlon". The material sold under the Registered Trade Mark "Dynel" is a synthetic fibre made by the copolymerization of 40% acrylonitrile and 60% vinyl chloride. Orlon is a synthetic fibre made principally from polyacrylonitrile. These acrylic fibres are present in the form of fine staple filaments and are spaced by animal fibres, such, for example, as by wool or by a material such as acetate fibres and nylon to prevent breaking and to reduce the shrinking of the acrylic fibres under heat. The woven binding fabrics 16, 18, and 20 are formed from yarns made up for the most part from inorganic, incombustible fibres such, for example, as glass fibres or metal. Preferably, glass fibres are employed and these fibres are twisted with a fibre of a material such as saponified acetate to improve the weaving characteristics of the fibres. While the binder fabrics 16, 18 and 20 are formed for the most part from glass fibre yarns, as is shown in Figure 2, the outboard weft yarns 22 and 24 are formed from a brushable material such, for example, as a blend of angora hair and fine wool. The inner fabric 12 just described, is a modified form of the fabric shown and described in the Specification of Patent No. 2,884,018 of the United States of America. In the fabric shown in the said Specification, only the lower weft yarns 24 are formed from brushable yarns. In the modified form of fabric shown in Figures 1 to 5, the upper weft yarns 22 are also formed from a brushable material to facilitate the application of a lead coating (to be described hereinafter) to both faces of the fabric 12 to obtain a greater surface area of the brushed material for the better adhesion of the lead particles. Preferably boron oxide is incorporated in the layer 12 to provide a neutron trap. This boron oxide may be in solution in alcohol or it may be in the form of a suspension of finely divided powder in water.

After having formed the heat resistant fabric layer 12 of this form of shield in the manner described hereinabove, both faces of the fabric 12 are brushed to raise respective piles 26 and 28 from the layers of weft yarns 22 and 24 as shown in Figure 3. When this has been accomplished on any suitable type of brushing machine known to the art, the faces of the heat resistant fabric 12 are coated with layers 30 and 32 of lead. This is accomplished by first spraying one face of the fabric and then spraying the other face. As is known in the art, the metal to be applied may be fed to a spray gun as wire or in powdered form. It is melted in an oxyacetylene or oxyhydrogen flame and blown out in finely divided form by an air blast. The spray consists of semi-molten particles which impinge on the faces of the

fabric 12 to form the adherent coatings 30 and 32. The piles 26 and 28 facilitate the operation of adhering the metal coatings 30 and 32 to the faces of the fabric 12. The coatings 30 and 32 each having, for example, a thickness of 1.25 mm., each afford the same protection as would a 3.5 mm. lead sheet under given circumstances, without making the fabric rigid.

It is to be noted that the fabric layer 12, which has a high resistance to heat, forms an excellent base for the reception of the coatings 30 and 32. This layer 12 inhibits the passage of the heat of the hot molten material from one face to the other of the fabric. Thus, after having applied the coating to one face of the fabric, the hot molten material is then sprayed on the other face without danger of destroying the fabric and without danger of melting the coating previously applied to the other face of the fabric due to the heat resistant qualities of the fabric as such.

It has been discovered that, as the coatings 30 and 32 applied to the faces of the fabric 12 harden, they tend to become rigid or brittle and may be peeled off. After the coatings 30 and 32 have been applied to the faces of the fabric 12 in the manner described hereinabove, the coated fabric is soaked in mercury for a period of approximately one hour. This operation softens the coatings 30 and 32 by the action of the mercury in forming an amalgam with the lead already applied to the faces of the fabric; at the same time the material of the coatings loses some of its cohesion.

Next, relatively thin woven fabric layers 34 and 36, are secured to the faces of the coated fabric by any suitable means. Any appropriate means may be employed for holding the layers of the ionizing radiation resistant thermal cloth in assembled relationship. In the form of shield as shown in Figures 1 and 4, quilting threads 42 are used for holding the outer fabric layers 34 and 36 assembled. It will be appreciated that such stitches 42 pierce the metal layers 30 and 32 to provide openings through which radiation may leak. To prevent such radiation leakage, lengths of a suitable pressure sensitive tape 44, having a coating 46 of lead or lead amalgam, are applied over the lines of quilting threads. These lead-coated lengths of tape effectively prevent leakage of radiation through the cloth. In an alternative form of cloth the cloth is stitched around its periphery with stitching 48. Any other suitable means for securing the fabrics 34 and 36 to the assembly may be employed. The fabrics 34 and 36 may be woven from any conventional textile material such, for example, as cotton or the like.

After having applied the thin fabric layers 34 and 36 to the assembly, any suitable means known to the art are used for applying outer abrasion-resisting coatings 38 and 40 to the assembly. The outer coatings may be formed for example, as a mixture including approximately fifty per cent by volume of lead and of neoprene. These outer layers 38 and 40 adhere to the outer surfaces of the thin fabric layers 34 and 36. With the application of these layers 38 and 40, the shield is complete in a form which is especially adapted for the manufacture of articles of clothing and the like as well as shields which are used to protect the various parts of the human body from the harmful effects of radiation in the course of radiation treatment or by means of curtains or garments in areas in which maintenance crews are working in the vicinity of sources of radiation.

Figure 6 shows the results of an actual test of a sample shield formed in accordance with the present invention. The abscissa is expressed in terms of mega-electron-volts while the ordinate is expressed in terms of equivalent shielding afforded by millimetres of lead. Curve A represents the radiation resistant effect of the sample shield. The lower portion of the curve was determined by use of an X-ray source of radiation while the upper region of the curve was determined using Cobalt 60 as a source of radiation. Curve B represents the radiation resistance of a sheet of lead having a weight which is the equivalent of the sample of the shield tested. A comparison of the two curves readily demonstartes the superiority in the higher radiation region of the sample shield over a specimen of lead which is the weight equivalent of the sample.

Referring now to Figure 7, another form of shield for ionizing radiation, indicated generally by the reference character 50, includes a base or carrier 52 which may be the thermal cloth referred to hereinabove, asbestos-glass cloth, aluminium screen, or any other more or less flexible support. In this form of the invention there is first applied to one or to both faces of the carrier 52 one or more coats 54 of a cement containing synthetic rubber such as neoprene or other plastic materials which are spread on the carrier 52 by any suitable means such as a spreader machine of a type known in the art. This neoprene cement may, for example, be made up in parts by weight of 100 parts of a synthetic rubber such as neoprene, 10 parts zinc oxide, 4 parts magnesium oxide, 10 parts antimony tri-oxide, 40 parts alumina, 1 part of a suitable accelerator, and 2½ parts of an anti-oxidant. This mixture is prepared in a manner known to the art by mixing it in a rubber mill and dissolving it in 400 parts of toluene. The resulting compound can readily be spread

on the face of the carrier by a knife or by rollers.

After having applied the layer of neoprene cement 54 to the carrier 52, a layer of lead amalgam 56 is next applied over the cement. One manner of preparing this amalgam is to mix 100 parts by weight of lead with 100 parts of mercury at a temperature of about 300° F. and allow it to cool to form an amalgam. When this has been done, the amalgam is placed in a bag and squeezed in a press to squeeze out an amount of mercury which is approximately equal to 50 parts of the original mixture. The solid mass remaining in the bag is placed in a ball mill and mixed with neoprene cement of the type described hereinabove. There are about 3 parts of cement solids to about 100 parts of amalgam solids. When this has been done, the mercury which previously was squeezed out is incorporated into the amalgam and cement mixture in the form of fine droplets by squeezing this mercury through a fine orifice under pressure and stirring the amalgam and cement mixture as the droplets are mixed in.

When the amalgam and cement mixture has been formed in the manner described above, it may readily be sprayed over the coating of neoprene cement 54 in as many coats as are desired to form a layer of the amalgam 56 of the desired thickness. After having applied the amalgam 56 over the layer of neoprene cement 54, coats of the neoprene cement are applied over the amalgam 56 to form a layer 58 of neoprene cement. If desired, these operations may be performed on both faces of the carrier 52. When these operations are complete, then the assembly is cured in a conventional manner.

It has been discovered that an amalgam made up of equal parts of lead and mercury is more effective as a shield against ionizing radiation than is an amalgam containing less mercury. The method described above of incorporating the lead and mercury amalgam into the cement has the additional advantage of preventing the migration of mercury to the lower parts of the layer or carrier after a period of time in storage of the assembly; that is, the neoprene cement prevents individual droplets of mercury from wandering in the compound. It is to be understood that, while the compound has been described as comprising a neoprene base, it could be modified with a phenolic plastic, or a silicone rubber compound having a high degree of heat resistance could be used.

In the form of the invention shown in Figure 7, the shield 50 may be assembled on a supporting cloth 60 or the like in the following manner. For example, there may be cemented on to the neoprene 58 before vulcanization, a strip 62 of strong cloth to form a fold or pleat 64 in the cloth. Stitching 66 may be employed for securing the strips 62 to the supporting cloth 60. In this manner it is not required that stitches pass directly through the amalgam 56. Also a strip 68 of strong fabric may be adhered over the edge of the shield 50 to form a loop 70. Loop 70 may be secured by stitches 72 to the supporting cloth 60. This manner of assembling the shield in a supporting cloth has the outstanding advantage that it avoids the need for passing stitches through the amalgam layer to detract from the efficiency of the shield in protecting against ionizing radiation.

Referring now to Figure 8, strips 74 may be secured between supporting cloths 76 and 78 by any suitable means such as by stitching 80 to form a plurality of pockets, indicated generally by the reference character 82, for receiving strips or lengths 84 of the shield. It is to be noted that, in the view shown in Figure 8, the strips 74 extend diagonally between the fabrics 76 and 78 so that the edges of adjacent lengths 84 overlap to prevent any gaps or spaces in the assembly through which ionizing radiation might pass.

Figure 9 shows an alternative means of forming pockets, indicated generally by the reference character 86. In this form of the invention, weft or filling threads 88 are floated diagonally between a lower fabric, indicated generally by the reference character 90, and an upper fabric, indicated generally by the reference character 92. After the floated yarns reach the upper fabric, they are woven into the fabric for a sufficient distance to hold the yarns in place. Each floated yarn then forms a loop 94 and is returned to the lower fabric 90 and is woven into this fabric until the next diagonal float is to be formed. When this has been done, the loops 94 are cut by any suitable means known to the art.

In the manufacture of the form of shield for ionizing radiation shown in Figures 1 to 5, the central layer 12 of heat resistant cloth is first woven with the rows of outer warps 22 and 24 of brushable material. When the fabric has been formed, both its faces are brushed to provide the piles 26 and 28. Lead particles are then deposited on to the piles 26 and 28 by means suitable to form the radiation resistant layers 30 and 32. After forming the coated faces of the fabric layer 12, the coated fabric is soaked in mercury to form a pliable amalgam making up the layers 30 and 32. When this has been accomplished, the thin fabric layers 34 and 36 are secured to the assembly by use of quilting threads or any other suitable means. Next, the outer faces of the thin fabric layers 34 and 36 are coated with a mixture of lead and an elastomer by any suitable method

known to the art to form the outer layers 38 and 40 which complete the radiation resistant cloth. When the cloth has thus been formed, garments of any type may be manufactured, or shields to any desired contour may be formed, from the finished fabric. In this form of the invention the strips 84 have been shown as including layers 54, 56 and 58 carried by a fibrous carrier 96.

It is to be noted that owing to the bulk afforded by the layer 12 of heat resistant cloth the layers 30 and 32 of lead may shift somewhat relative to each other to provide a high degree of pliability in the fabric. At the same time the layers 30 and 32 afford the same degree of protection against radiation as does a relatively rigid sheet having greater thickness and weight than the combined layers 30 and 32. The brushed piles 26 and 28 provide the maximum surface area to which the aprayed lead coating can adhere.

In the manufacture of the form of the invention shown in Figure 7, the neoprene cement 54 is first applied to one or both faces of the carrier 52. Next the amalgam paste or dough is formed in the manner described above and is applied over the neoprene layer 54 in a number of coats to build up a thickness to give the required degree of protection against ionizing radiation. When this has been accomplished, the outer layer of neoprene cement 58 is applied. After curing in a conventional manner, the shield is assembled on a support cloth 60 as shown in Figure 7; or alternatively it may be assembled either in the manner shown in Figure 8 or in the manner shown in Figure 9.

It will be seen that there has been provided a shield for ionizing radiation which affords a high degree of protection against ionizing radiation, while at the same time being pliable to permit its formation into shields having various shapes. The shield has greater resistance to penetration by ionizing radiation than does the equivalent weight of lead, and has sufficient structural strength to support its own weight without rupturing. At the same time it has good structural stability so that it will not deform on a bias when in use. Further, the shield affords the same degree of protection as does a relatively rigid sheet of the prior art at lesser weight under given circumstances. The shield may be made to have a high degree of resistance upon exposure to heat for a prolonged period of time.

WHAT WE CLAIM IS:—

1. A shield against ionizing radiation comprising a base layer and a layer including lead amalgam secured to the base layer.

2. A shield according to Claim 1 in which the base layer is a fabric layer.

3. A shield according to Claim 1 or Claim 2 in which the base layer is heat resistant.

4. A shield according to Claim 3 in which the base layer includes filler yarns made up to a major portion of acrylonitrile polymer.

5. A shield according to any one of Claims 1 to 4 in which the base layer carries a minor quantity of boron oxide.

6. A shield according to any one of Claims 1 to 5 in which the lead amalgam is formed from substantially equal quantities of lead and mercury.

7. A shield according to any one of the preceding claims in which the surfaces of the base layer include a brushable material.

8. A shield according to any one of the preceding claims in which a further layer including lead amalgam is secured to the other side of the base layer.

9. A shield according to Claim 8 in which a fabric layer is secured over each lead amalgam layer..

10. A shield according to Claim 9 in which the layers are held together by quilting stitches and including tapes with coatings comprising lead covering the quilting stitches.

11. A shield according to Claim 9 or Claim 10 including an abrasion resistant layer overlying each of said outer fabric layers.

12. A shield according to any one of Claims 1 to 6 in which the lead amalgam layer is secured to the base layer by a layer of adhesive.

13. A shield according to Claim 12 including a protective layer of rubber-like material overlying the lead amalgam layer.

14. A shield according to any one of Claims 1 to 6, 12 or 13 including pleated strips secured to the assembly of the base layer and lead amalgam layer, and a supporting member secured to the pleated strips by stitching.

15. A shield against ionizing radiation comprising a plurality of lengths of material each including a base layer and a layer including lead amalgam and a carrier formed with pockets for receiving the lengths, the side walls of the pockets extending diagonally such that the edges of said lengths overlap.

16. A method of making a shield resistant to ionizing radiations comprising the steps of brushing the opposite faces of a base layer of thermal cloth to raise piles on the faces, applying lead amalgam layers to said faces and retaining the lead amalgam layers on the base layer.

17. A method of making a shield resistant to ionizing radiations comprising the steps of brushing the opposite faces of a base layer of thermal cloth to raise piles on the

faces, applying layers of lead to the faces, treating the coated base layer with mercury to form lead amalgam, removing the excess mercury from the amalgam and retaining the amalgam layers on the base layer.

18. A shield against ionizing radiations substantially as described herewith with reference to Figures 1 to 5, Figure 7, Figure 8 or Figure 9 of the accompanying drawings.

19. A method of making a shield substantially as herein described.

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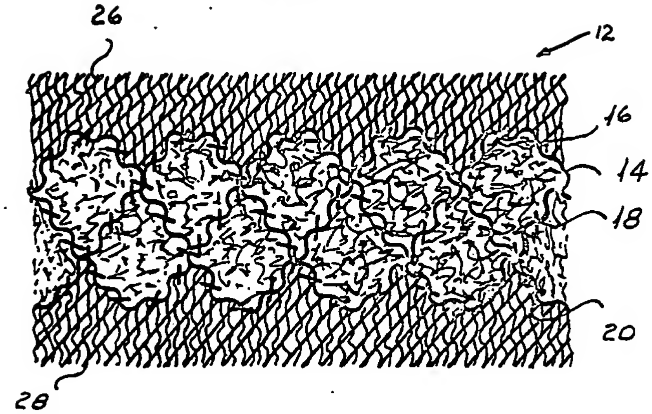
Fig 3



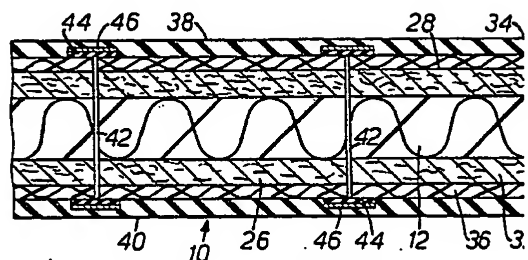


FIG. 1.

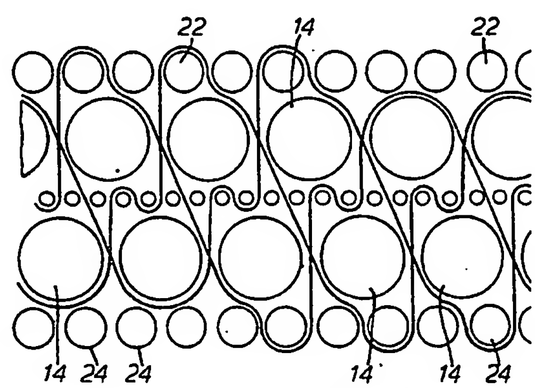


FIG. 2.

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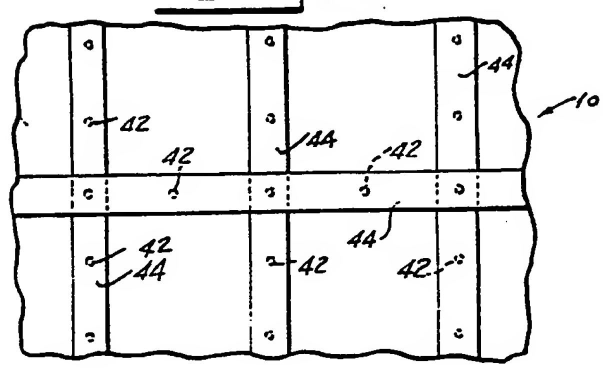
Sheets 1 & 2

Fig 4



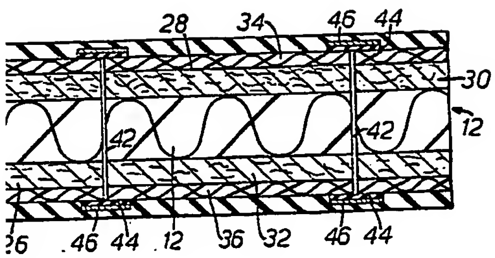
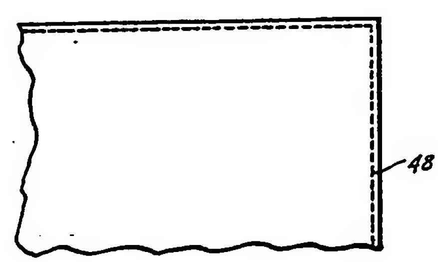


FIG. 1.

Fig 5



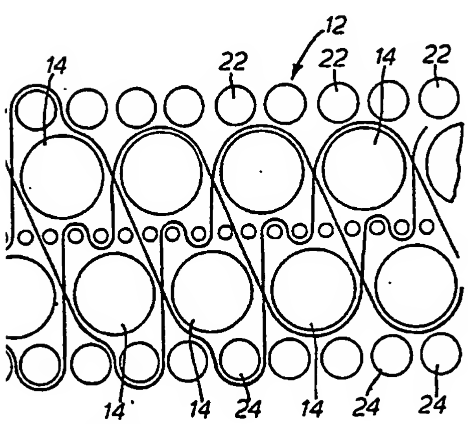


FIG. 2.

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Fig 3

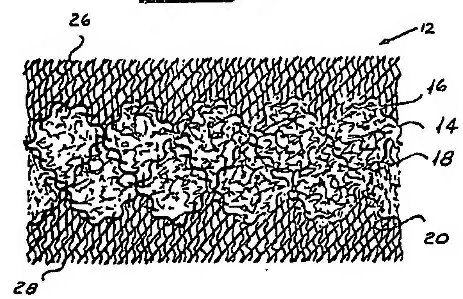
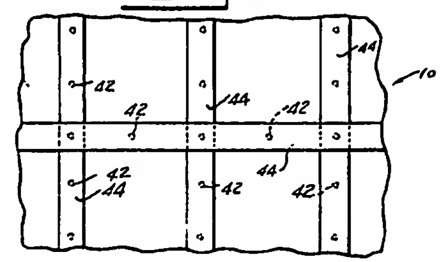


Fig 4



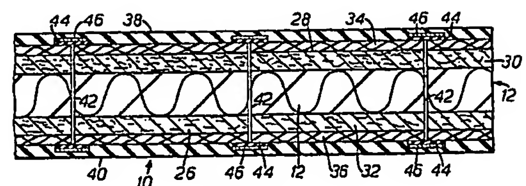
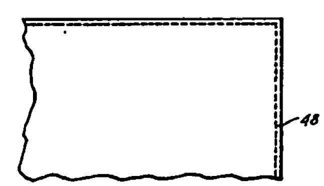


FIG. 1.

Fig 5



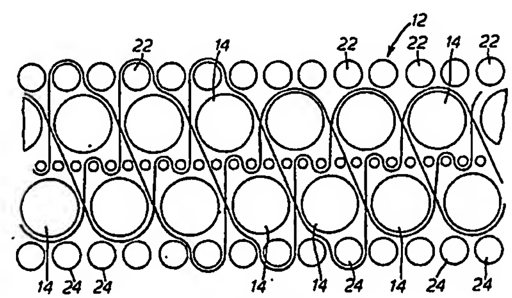


FIG. 2.

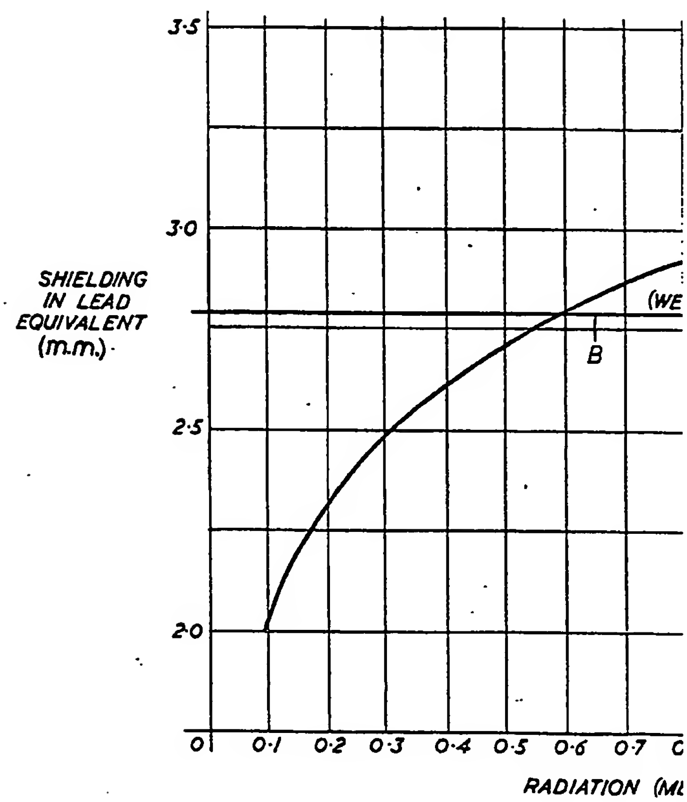

SHIELDING
IN LEAD
EQUIVALENT
(m.m.)
3·5
3·0
2·5
2·0
(WE
B
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
RADIATION (M

FIG.

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Sheet 3

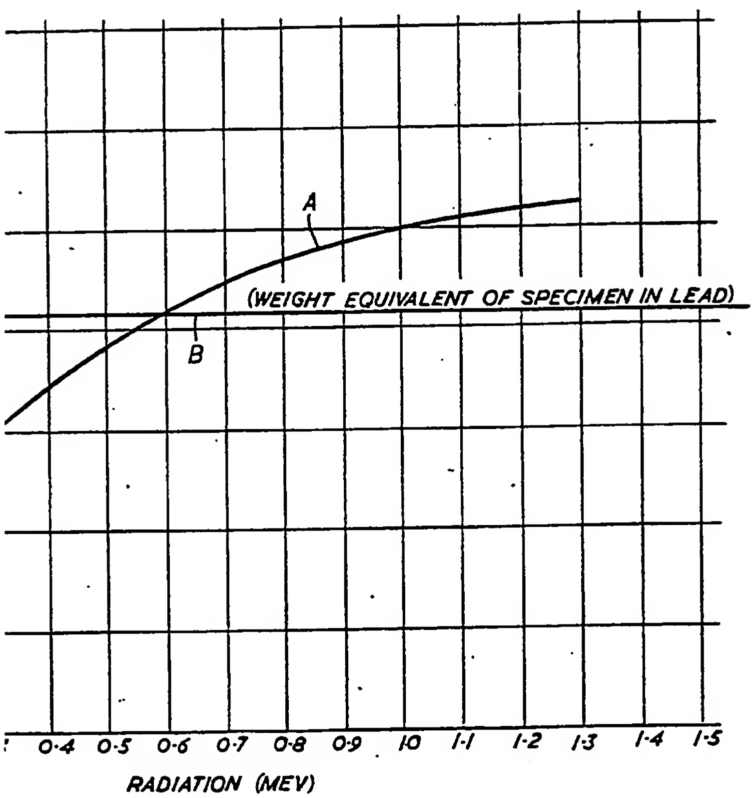
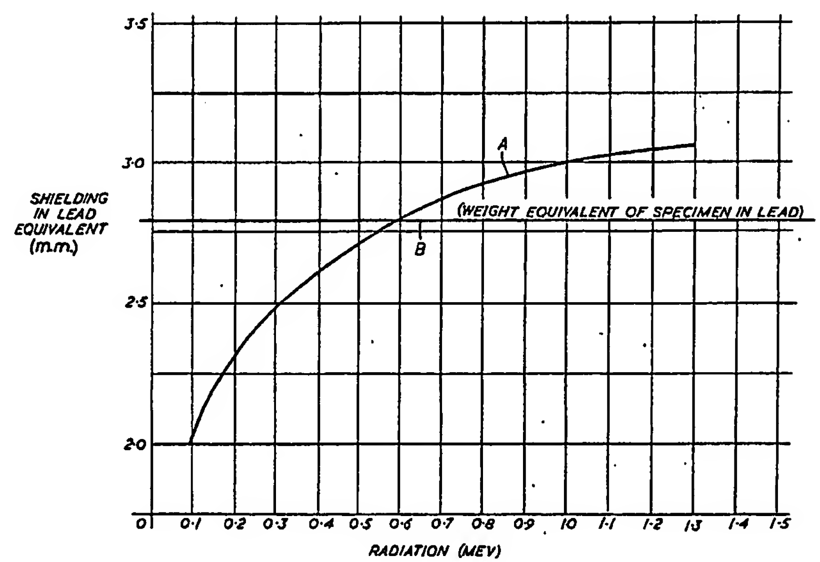


FIG. 6.


SHIELDING IN LEAD EQUIVALENT (m.m.)
3·5
3·0
2·5
2·0
0
0·1
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0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
1·1
1·2
1·3
1·4
1·5
RADIATION (MEV)
A
B
(WEIGHT EQUIVALENT OF SPECIMEN IN LEAD)

FIG. 6.

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Sheet 4

Fig 7

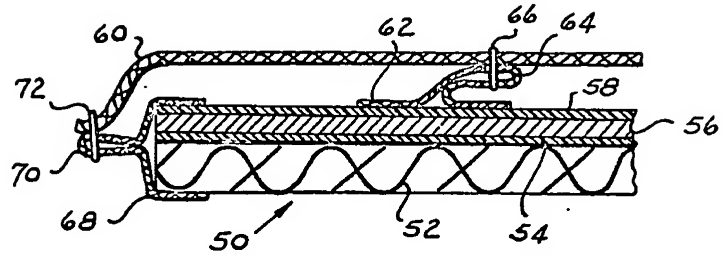
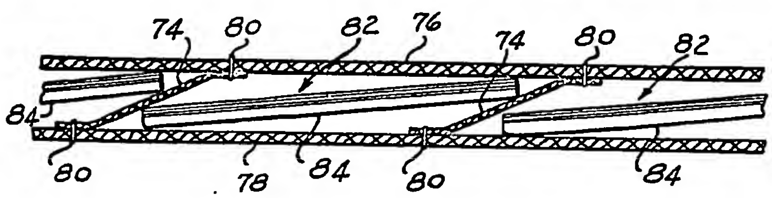


Fig 8



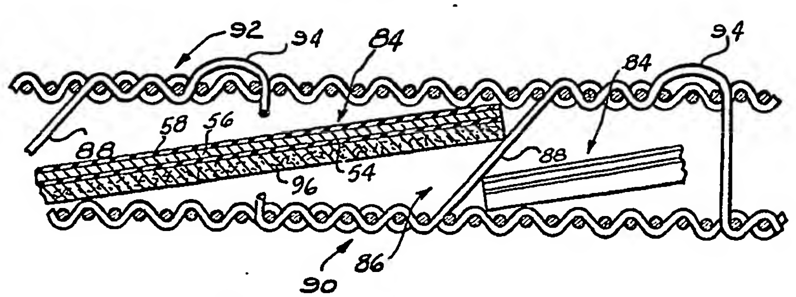


Fig 9